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Four hundred and twentieth meeting.

November 14, 1855. — STATED MEETING.

The PRESIDENT in the chair.

The following gentlemen were elected Fellows of the Academy, viz. : —

John C. Gray, of Boston, Professor James Russell Lowell, of Cambridge, Professor Francis J. Child, of Cambridge, and Richard Greenough, of Boston, in the Section of Literature and Fine Arts.

Rev. William A. Stearns, D. D., of Amherst, in the Section of Philosophy and Jurisprudence.

Professor Albert N. Arnold, of Newton, in the Section of Philology and Archæology.

The following, nominated by the Council, were elected Foreign Honorary Members, viz. : —

Dr. Fr. W. A. Argelander, of Bonn, in the Section of Astronomy.

Victor Regnault, of Paris, in the Section of Physics and Chemistry.

L. D. Vicat, of Paris, in the Section of Technology and Engineering.

Richard Owen, of London, in the Section of Zoölogy and Physiology.

Sir Benjamin Brodie, of London, and P. Rayer, of Paris, in the Section of Medicine and Surgery.

Archbishop Whately, of Dublin, and Victor Cousin, of Paris, in the Section of Philosophy and Jurisprudence.

Franz Bopp, of Berlin, and Friedrich von Thiersch, of Munich, in the Section of Philology and Archæology.

François Guizot, of Paris, in the Section of Political Economy and History.

Professor Gray laid before the meeting a bronze medal commemorating the three eminent botanists, Bernard, Antoine Laurent, and the late Adrien de Jussieu: presented by the Jussieu family.

Professor Joseph Lovering asked the attention of the Academy to the following remarks on motions of rotation.

“Since the time of Foucault’s celebrated experiment for illustrating the rotation of the earth by the stability of the plane of oscillation, increased attention has been given to the law of *inertia* as determining the stability of *planes* of motion. The planes of *rotation* conform to this general rule of stability. Astronomy furnishes the only examples of perfectly free rotating bodies: and astronomy, here, as elsewhere, must be invoked, whenever it is required to give an exact experimental illustration of the fundamental laws of mechanics. Artificial experiments realize but imperfectly this perfect freedom of the spinning earth and other planets. Besides the top and the *devil-on-two-sticks*, in which ‘philosophy in sport has been made science in earnest,’ there are Bohnenberger’s less familiar apparatus, first described in 1817,* and Johnston’s Rotascope.† The necessity has recently been shown of adding to the description of the former the new *condition* of placing the axis of the apparatus parallel to the earth’s axis to avoid the disturbance of the earth’s rotation, and the new *application* of the instrument, when otherwise placed, to detecting this rotation.‡

“In 1853, Plücker published an account of Fessel’s apparatus for experiments on the laws of rotation;§ and in 1854, Magnus presented to the public an account of his *Polytrop*, also designed for similar illustrations.||

“1. Plücker preludes his description of the Fessel machine with some remarks on Poisson’s mathematical investigations on the subject of rotations,¶ and alludes to Poinset’s successful attempt to make the motions generally hidden under the veil of mathematical analysis more sensible to the imagination and the eye.** Poinset thinks that, if many new truths are contained in analysis, they are buried in it for all but a few gifted minds. ‘Thus our true method is but this happy mixture of analysis and synthesis, where calculation is employed only as an instrument, a precious instrument, and necessary without doubt, because it assures and facilitates our progress; but which has of itself

* Ann. Gilbert, LX. p. 65.

† Silliman’s Journal, XXI. p. 265.

‡ Ann. Pogg., XC. pp. 350, 351.

§ Ann. Pogg., XC. p. 174.

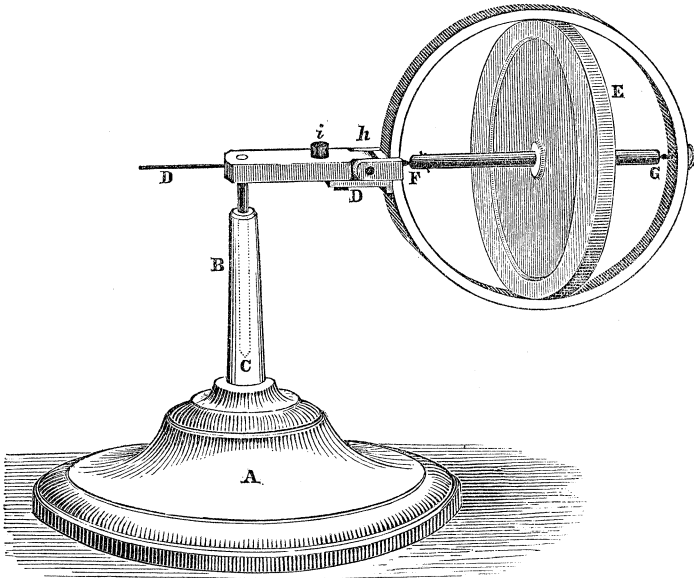
|| Ann. Pogg., XCI. p. 298.

¶ Journ. de Polytechn. Ecole, XVI. p. 247.

** Elemens de Statique, 8th edition, 1842.

no peculiar virtue ; which does not direct the mind, but which the mind must direct like any other instrument.'

“The origin of Fessel’s machine was as follows. About 1851 this skilful artist of Cologne, who a few years before had distinguished himself by his beautiful *Wave-machine*, particularly adapted for illustrating the mechanical laws of light, was examining the wheel of a model steam-engine, and observed that, while rolling it on his hand, the horizontal axis did not require to be supported at both ends, while there was a tendency in the axis to move in a horizontal plane. Fessel’s practical skill, aided by the suggestions of the eminent physicist Plücker, resulted in the construction of the following apparatus.



The wood-cut represents the apparatus, not exactly as figured in the *Annalen of Poggendorf*, but as constructed by Luhme, and now exhibited. It is about half the size of the model. Upon a heavy base, A, stands a hollow brass column, B, inside of which turns a steel pin, C, terminating at the lower end in a point. At right angles to this pin are fastened the metallic arms D D. On one of these arms, and at the distance of two inches from the pin, is fastened a vertical ring. Inside of this ring is placed a metallic disc, E, loaded at the edge ; and which turns, independently of the ring, upon the axis F G. The motion is communicated by a thread wound upon the axis of the disc. At h is

a hinge, working on a horizontal point, which allows the ring containing the disc to move in its own plane. This motion can, however, be prevented by a revolving slide underneath. In some experiments the slide is placed so as to prevent the motion on the hinge, and the arms are balanced upon a fixed and pointed rod which is pushed into the brass column. For this purpose there is a little cap under *i*, and a counterpoise which slides on the opposite arm to balance the disc. The top has less friction than Bohnenberger's or Fessel's apparatus. Also in Fessel's machine the disturbing force is the whole weight of the disc and ring, and not, as in Bohnenberger's machine, simply an excess of weight on one side of the rotating body. Hence the precession is more rapid in the first than in the last.

"If the disc is not rotating, it naturally drops down upon the hinge *h*, from its own weight.

"But when the disc is made to rotate rapidly by means of the thread, and then left free, it seems indifferent to gravity, and, instead of dropping, it begins to revolve about the vertical axis. So that the axis of the disc acquires a motion similar to the *Precession of the Equinoxes* in Astronomy. The motion of revolution is opposite in direction to the rotation of the disc. When one of these motions is the greatest, the other is the least. If the motion of revolution is increased artificially, the disc appears lighter. If this motion is retarded, the disc appears heavier. Reciprocally, if the gravity of the disc is artificially increased, the motion of revolution is greater. If the gravity of the disc is artificially diminished, the motion of revolution is less. This variation in the gravity of the disc is easily effected upon an iron disc by means of a magnet. If the action of gravity is prevented by the slide which confines the hinge, there is no motion round the horizontal axis.

"The following popular explanation is given of these peculiarities of motion.* Place the disc in a vertical plane and make it rotate. The tangential motion of each particle has a horizontal and vertical component. As soon as the disc begins from its weight to incline from its original vertical position, the horizontal components still remain parallel to the new position, but the vertical components do not. If the upright edge of the disc nearest to the eye is ascending, this edge is pushed to the left and the opposite edge to the right. These two forces, resulting out of the deviation of the original vertical

* Ann. Pogg., XC. p. 348.

components from parallelism with the disc, act as through a bent lever to turn the whole disc round a vertical axis in a direction opposite to its rotation. This can be shown experimentally by pressing with the fingers upon these two parts of the edge. As soon as the motion round the vertical axis begins, the horizontal components of the original rotation no longer retain their parallelism with the disc. But the tendency to preserve this parallelism, in other words, the tendency of the disc to preserve unchanged its plane of rotation, generates forces which act on the top of the wheel to the left and on the bottom of the wheel to the right. These forces, acting by leverage, tend to lift the wheel, as may be seen by pressing in the same way with the fingers. When friction is excluded, this uplifting force is an exact balance of gravity, and the wheel neither rises nor falls.

“The results of these experiments are remarkable, as showing how differently gravity acts upon a body at rest and upon the same body in motion. When it acts upon a body at rest, it tends to give it a motion round a horizontal axis, but not about a vertical axis. When a body is rotating in a vertical plane, gravity tends to give it no descending motion round a horizontal axis, but simply to turn it upon a vertical line. This apparent mechanical paradox is beautifully illustrated in the *Precession* of the Equinoxes. The disturbing influence of the sun and moon, which represent the gravity to be considered in this astronomical example, would make the equator drop down into coincidence with the ecliptic, if the earth were not spinning on its axis, and would make the precession an unknown phenomenon. But the same forces, acting upon the rotating earth, move the line of equinoxes backward, and leave the obliquity essentially unchanged. It follows, from the experimental illustration, as well as from the mathematical theory, that, if the disturbing forces were greater, the precession would be greater; and if the earth's rotation were diminished, *ceteris paribus*, the precession would be increased.

“2. The *Polytrop* of Magnus consists of two rotating vertical discs, arranged upon an axle, as the two wheels of a carriage. These discs can be set in motion by cords wound upon the hub of each disc, the free ends of the cords being attached to the same handle. The axle which carries the discs is movable at its centre around a vertical and also a horizontal axis, but either of these motions can be prevented at pleasure. If both discs are made to rotate in the *same* direction, or if only one disc rotates, it is not easy to turn the whole apparatus on

its horizontal axis. But if the machine is prevented from moving round a vertical axis, there is no difficulty in disturbing it around its horizontal axis.

“ Thus it appears in this experiment, as well as in those made with the Bohnenberger and Fessel machines, that a force acting upon a free body is prevented from producing motion in *its own direction* by the conical motion which exists around a rectangular axis. The same experiments can be made with the Bohnenberger apparatus, by holding or releasing the middle ring. In mechanics, a body has lost its stability of rotation when it has lost its freedom: and the most complete stability is consistent with perfect freedom. Astronomy hangs up for ever in the sky a splendid illustration of this principle. It cannot be that a less noble law prevails in the kingdom of mind than in that of matter. When the two discs are made to rotate in opposite directions with the same velocity, there is no stability, even when the apparatus is most free. For the tendency of the two rotations when combined with a foreign disturbance being to produce equal and opposite conical motions, the result is the same want of stability as if there was no conical motion in either direction.” *

Professor Felton made a short communication on the Pnyx and Bema, at Athens. He remarked that Greek topography is to a great extent a restored science, indebted for its present form and precision to the labors of modern scholars, and to none so much as to Colonel William Martin Leake. A map was exhibited, on which the physical features of Athens were delineated, and the sites of the principal antiquities indicated. Another map was also shown, exhibiting the hill of the Pnyx, with the Bema, carefully drawn according to their exact measurements. The meaning of the names was explained, and it was remarked, that, if these objects are what they are now generally supposed to be, the spot is not only one of the most interesting in Athens, but in the world. The references in the ancient writers were then reviewed in the following order: — 1. Thucydides, B. C. 471. 2. Aristophanes, 444, in several plays, — the Acharnians, Ecclesiazousæ, Knights.

* Ann. Pogg., LXXXVIII.

3. Plato, 429, in Critias, descriptive of a former imaginary condition of Athens. 4. Æschines, 389. 5. Demosthenes, 385. It was remarked, that, during the Macedonian and Roman periods, the Pnyx was not used, and is only mentioned incidentally, or by way of allusion. 6. Plutarch, A. D. 40, in the Life of Theseus and Life of Themistocles, an anecdote of the Thirty Tyrants. 7. Lucian, 120, in the Fishers. 8. Julius Pollux, 183. 9. Timæus, 3d century A. D., in Lex. Plat. 10. Hesychius, 380. 11. Proclus, 412, Commentary on Plato. 12. Soudas, in the eleventh century. Then came the Crusaders, and the periods of the Dukes of Athens, and of the Turkish domination, during which the knowledge of Athenian topography almost disappeared.

The opinions of the early modern travellers were mentioned. In the seventeenth century, Spon thought it was the Areiopagos: Wheeler, the Areiopagos or Odeion. In the eighteenth century, Stuart and Revett believed it to be the Theatre of Regilla. Chandler, 1765, expressed the opinion that the structure was the Pnyx, or place of the popular assemblies of the ancient Athenians, and from that day to a recent period no doubt has been entertained that the levelled space, supported below by a heavy polygonal wall, was the Pnyx, and that the stone platform was the Bema, or stand on which the orators took their place when they addressed the people.

In 1836, the University of Athens was founded, and Professor Ulrichs, one of the German scholars appointed to a chair in the institution, began to entertain doubts of the correctness of the received opinion. In 1842, Professor Welcker of Bonn, one of the most eminent scholars of Europe, visited Athens, and, in company with Ulrichs, went up to the Pnyx. On examining the place, he found reason to coincide with the impressions of Ulrichs. Since that time he has carefully studied the subject, and in 1852 published in the *Abhandlungen der Königlich Academie der Wissenschaften* of Berlin a very elaborate dissertation, in which he embodies the results of his studies, and arrives at the conclusion that the Bema is an

ancient altar to Zeus Hypsistos, or Jupiter the Highest, and that the levelled space, with the old supporting wall, is the ancient *Pelasgicon*. This essay was answered by Professor Ross, formerly of Athens, now of Halle, in a pamphlet, published in 1853. Welcker replied by another pamphlet in 1854.

Professor Felton gave a summary of the arguments on both sides, and stated that the subject had occupied much of his attention while in Athens;—that he had come to the conclusion that the received opinion is correct;—and, in confirmation of this view, went at some length into an examination of the authorities, especially Plato, Demosthenes, Plutarch, and Proclus, citing a passage from the last-mentioned author which had never been considered before, and which was pronounced to be almost, of itself, conclusive: and quite conclusive, as the last term in a cumulative argument, the expressions being precisely applicable to the shape of the supposed Pnyx, and to no other place or structure in Athens.

Four hundred and twenty-first meeting.

December 11, 1855. — ADJOURNED QUARTERLY MEETING.

The PRESIDENT in the chair.

The following gentlemen were elected Associate Fellows; viz.:—

Rev. Moses A. Curtis of South Carolina, and Professor Charles W. Short, M. D., of Louisville, Ky., in the Section of Botany.

Drs. J. P. Kirtland, of Cleveland, Ohio, and J. C. Dalton, Jr., of New York, in the Section of Zoölogy and Physiology.

Professor Dennis H. Mahan, of West Point, in the Section of Technology and Engineering.

Hiram Powers, Thomas Crawford, William C. Bryant, and Washington Irving, in the Section of Literature and the Fine Arts.

Professor W. B. Rogers exhibited to the Academy a set of Schönbein's test-papers for ascertaining the amount of ozone